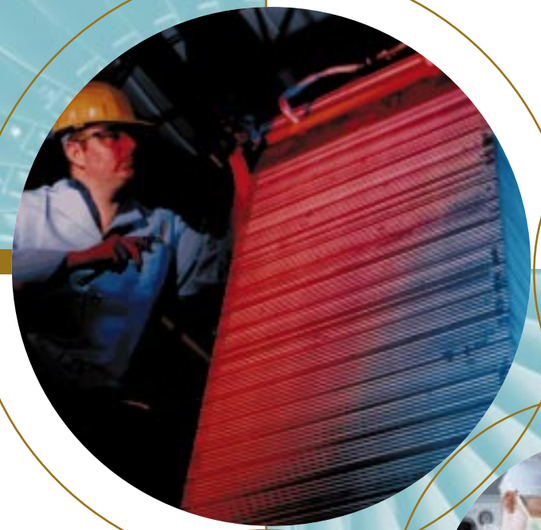
# DISTRIBUTED GENERATION

OPTIONS FOR TOMORROW'S ENERGY MIX

reliable



DISTRIBUTED GENERATION SYSTEMS OFFER POWER PRODUCERS EASE OF SITING, MODULAR CONSTRUCTION OPTIONS, ENVIRONMENTAL BENEFITS, AND HIGH EFFICIENCY.

flexible

PROGRAM AREAS

- Fuel Cells
- Advanced Gas Engines
- Combined Heat and Power

## INTRODUCTION

### BOTH BASELOAD AND DISTRIBUTED GENERATION ARE NEEDED

As the U.S. moves to competitive utility markets, decisions on alternate power generation technologies will be based in large part on system costs and capital outlays. Distributed generation has many advantages to offer the energy industry. Distributed generation could augment the traditional central station grid system in relatively remote locations where upgrading the existing transmission grid would be more costly than installing a distributed generation system; and at sites requiring 100% availability (such as hospitals and industrial or commercial facilities where cogeneration loads can help make distributed generation economical). A report prepared by the Gas Research Institute estimates that gas-fueled distributed generation capacity could be as high as 6,000 megawatts (MW) per year for baseload fuel cells in 2010.

Distributed generation systems will be used largely in markets not served by centralized power. Some requirements for distributed generation systems to achieve their full market potential include:

- ***Low cost.*** In the U.S., technology selection will be based in large part on cost. Fuel cells and advanced heat engines are being designed to offer cost-effective energy solutions.
- ***Very high reliability***. Distributed generation systems must be robust because they will be used and maintained by companies that are not as experienced as powerplant operators and engineers in central power station facilities. Fuel cell systems have already performed reliably for long periods of time without complex or time-consuming repairs.
- ***Flexible size configurations.*** Availability in a variety of sizes from kilowatts (kW) to tens of megawatts is a key attribute of distributed generation technologies.
- ***Modular construction.*** The modularity of distributed generation technologies increases their flexibility to meet changes in demand as efficiently as possible.
- ***Environmental acceptability.*** Since many distributed generation systems may be located in communities near demand centers or in remote, environmentally pristine areas, their environmental performance must be extremely high.
- ***Rapid startup.*** Some distributed generation technology can meet peaking, intermediate load, and load following needs.
- ***Power quality.*** Distributed generation offers many ancillary benefits including voltage control, reactive power control, and regulatory control.

## BENEFITS TO THE NATION

***Industrial and commercial growth.*** Growth of U.S. industry will be supported by maintaining distributed generation technical rights and ownership, and by forming engineering and manufacturing infrastructures for distributed generation technologies within the U.S. Domestically manufactured goods can then be sold to world markets.

***Reduced electricity costs.*** Distributed generation systems will result in reduced costs for electrical and heating/cooling systems expansion, as they do away with the need to transport electricity or heat and allow expansion of existing facilities in small increments.

***Increased reliability***. Power quality and reliability will be increased because distributed generation systems are not subject to transmission line and network voltage fluctuations, and because they are installed near end-use markets.

## STRATEGIES FOR SUCCESS

The Distributed Generation Program is based on extensive participation with the private sector and other government agencies (such as DOE's Office of Energy Efficiency and Renewable Energy) for the development of fuel cells and advanced heat engines for stationary applications. Cogeneration and district heating are important elements of the program.

The program implements RD&D that promotes timely demonstration of fuel cell systems, focusing first on resolving technical issues, including cost reduction and packaging. Particular emphasis is placed on conducting the appropriate basic research and technology transfer to assist in commercialization.

Having established a consortium of U.S. engine manufacturers, engine users, and research institutions to evaluate developmental needs for an advanced gas engine, DOE is determining its role in cooperative research programs required to address public needs.

## FUTURE ACHIEVEMENTS FOR DISTRIBUTED GENERATION

Measurable goals for DOE and industry partnerships are to:

- Yield commercial offerings of fuel cell powerplants in the 200-kW to 3-MW range.
- Lower fuel cell powerplant costs to under $1,500 per kW by 2003.
- Achieve fuel cell electrical conversion efficiencies of between 50% and 60%.
- By 2010, commercialize U.S.-manufactured advanced gas engines with 20% higher brake efficiency, 75% lower $NO_X$ emissions, and lower cost compared to current engine technology.
- Demonstrate distributed generation technologies, such as advanced fuel cells and heat engines, in cogeneration and district heating/cooling applications with overall system efficiency reaching 85%.

## FUEL CELLS

Fuel cells generate electricity and heat using an electrochemical process superior to that of a battery. A fuel cell continuously produces power as long as a fuel, such as natural gas, and an oxidant (air) are supplied. Present systems can exceed 50% electrical efficiency, based on the fuel's lower heating value. Next-generation systems are expected to achieve over 70% and, eventually, greater than 80% efficiencies.

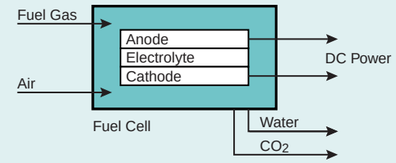
The Fuel Cell Program is being driven, in part, by the emergence of distributed generation approaches and deregulation of the electric power industry. Fuel cells offer greater customer choice; greater siting flexibility; the capability to use "opportunity fuels," such as gas produced in landfills; reduction of capital investment and risk; a highly efficient, reliable, and environmentally benign source of electricity; and elimination of transmission and distribution problems.

Maintaining U.S. leadership in the technology race is crucial in capturing world fuel cell markets. It is important to maintain the current technological edge in significant technologies and U.S. ownership and intellectual property rights in critical areas. This is being accomplished through the establishment of engineering and manufacturing infrastructures in the United States for new fuel cell industries.

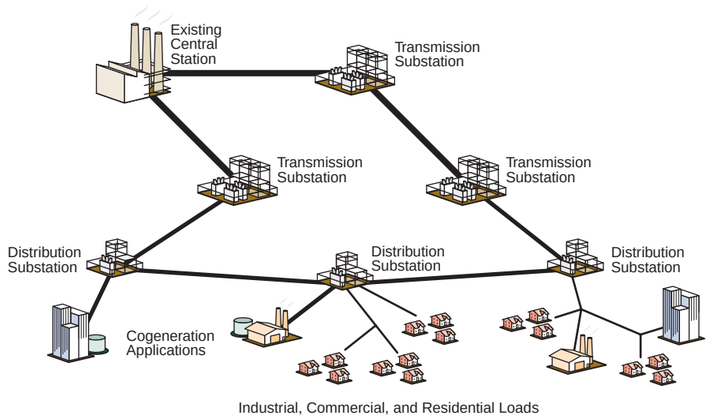
The Fuel Cells Program focuses on the development of highly efficient, environmentally benign, high-temperature fuel cell power generation technologies, such as molten carbonate fuel cells (MCFCs) and solid oxide fuel cells (SOFCs). It includes the integration of components for proof-of-concept testing, customer tests of subscale integrated systems, and eventual commercial demonstration of full-scale systems.

### FUEL CELL DIAGRAM

A basic fuel cell consists of two electrodes, an anode, where the fuel is introduced, and a cathode, separated by an electrolyte. It produces DC power that is easily converted to common AC power by an inverter, and hot water for use in buildings or industrial processes. Fuel cell types are characterized by their electrolyte and corresponding operating temperature. For example, MCFCs use a mixture of carbonate salts as the electrolyte, which is a liquid at the fuel cell operating temperature of about 650°C. In contrast, SOFCs use a ceramic electrolyte that remains solid at their 1,000°C operating temperature.



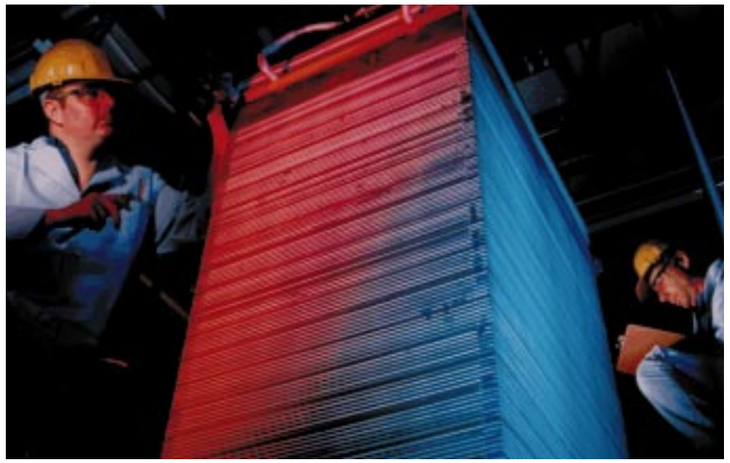

### DISTRIBUTED POWER GENERATION




*Distributed generation will offer utilities the opportunity to match the electricity demand of individual customers by providing reliable on-site generation. In this example, electricity is being produced at distributed generation substations located near electricity users. These distributed sources of electric power may, but are not required to, be connected to the central electrical transmission lines.*

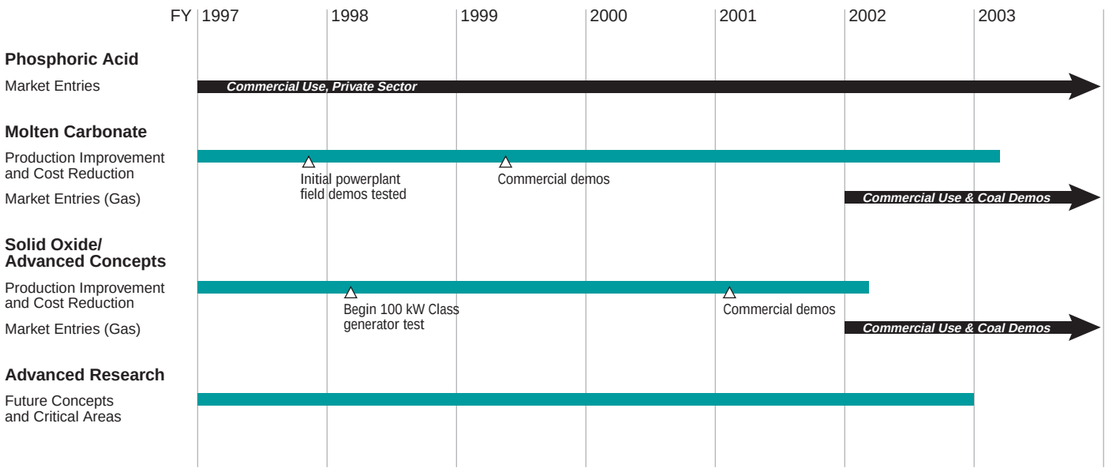
## FUEL CELL PROGRAM ACCOMPLISHMENTS

- Over 160 phosphoric acid fuel cell (PAFC) units manufactured and operating worldwide.
- 250 kW and 2 MW molten carbonate fuel cell (MCFC) product development tests completed. 300 kW to 1 MW demonstration planned.
- 100 kW solid oxide fuel cell (SOFC) demonstration being conducted. Additional 100 kW to 1 MW demonstrations planned.
- Fuel cells and fuel cell/turbine hybrids are enabling technologies for Vision 21 concepts.



*To produce a usable quantity of electric power, individual cells are assembled into a "stack" of electrically interconnected repeating components. This MCFC stack developed by Energy Research Corporation is made up of around 300 cells, with an area of 8 square feet.*
*A fuel cell powerplant consists of one or more stacks integrated into a power section, which is then linked to a fuel processor and a power conditioner to convert the power from direct current (DC) to alternating current (AC).*

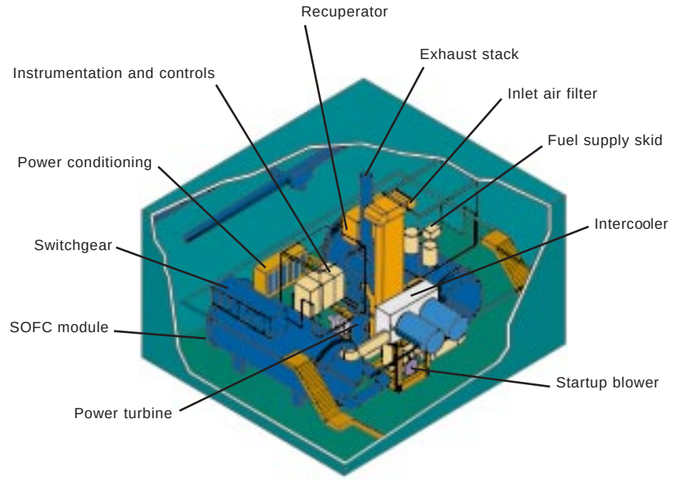
## ROADMAP FOR FUEL CELLS PROGRAM








## SOLID OXIDE FUEL CELL POWERPLANT LAYOUT




## FUEL CELL REBATE PROGRAM

With fuel cells, as with most other products, increased manufacturing volume lowers cost, increasing market penetration. To help increase market penetration, the Fuel Cell Rebate Program (also called the Climate Change Fuel Cell Program) was begun in 1996 using funds provided by the Department of Defense (DOD), Office of Deputy Under Secretary of Defense for Environmental Security.

Rebates are given to organizations installing a fuel cell manufactured in the U.S., with priority given to powerplants placed on DOD installations.

Rebate program status:

- In 1996, 33 grants of $1,000/kW (or a maximum of one-third of project costs) were awarded, resulting in sales of 42 fuel cell powerplants (200 kW) representing a crosscut of market potential.
- In 1997, 53 grants were awarded.
- In 1998, an additional $5 million was provided for awards to be announced in 1999.

## ADVANCED GAS ENGINES

As the need for distributed power generation emerges, continued global market growth is projected for gas-reciprocating engines and industrial-scale gas turbines. Advanced industrial-scale turbines are being developed under the Advanced Turbine Systems (ATS) Program.

Projected growth in natural gas use will increase the Nation's need for efficient and clean gas-reciprocating engines. Orders for natural-gas-reciprocating engines were 38% higher in 1996 than in 1995. Assuming this market growth trend continues, improving the efficiency and reducing the cost of these engines will have significant environmental and consumer benefits.

Environmental constraints continue to become more stringent as policies to reduce greenhouse gas emissions and as regulations for non-attainment areas become more restrictive. Development of advanced gas-reciprocating engines would provide cost-effective products to enable engine users to comply with possible new climate change and air emissions standards.

U.S. manufacturers today are at a disadvantage with respect to foreign manufacturers. Foreign products are more efficient, less polluting, and cheaper. Developing advanced gas-reciprocating engines would provide U.S. manufacturers with a competitive edge in the global engine market.

DOE is organizing workshops and meetings to evaluate the need for a cooperative research program to develop advanced gas engines.

## COMBINED HEAT AND POWER

Cogeneration is the simultaneous production of heat or cool air and electrical power in a single process or from a single piece of equipment. The heating or cooling produced can then be used in industrial processes or district-heating systems that distribute steam, temperature-controlled water, or air to multiple sites or buildings. Currently, district heating or cooling is provided by cogenerating plants or facilities designed specifically for this service.

By the end of the next decade, environmental requirements for all power systems may create significant opportunities for cogeneration and district heating. Electricity generators could reduce emissions while achieving the greatest return on investment and the highest efficiencies (about 85% higher heating value) by using high-tech cogeneration and district-heating systems. Capital costs associated with cogeneration and district-heating systems continue to be the main impediment to their use. All DOE advanced fossil-power systems can be adapted to cogeneration and district-heating operations.

Fuel cells, advanced gas turbine systems, and integrated gasification combined-cycle systems will have less impact on the environment if coupled with cogeneration applications.

These benefits are being demonstrated by the Fuel Cell Program in a small 100-kW district-heating program in the Netherlands, and at the Miramar Naval Air Station in Southern California. The Fluidized-Bed Combustion (FBC) Program has also worked with Alaskan Native groups to investigate the adaptation of coal-fired FBC cogeneration and district heating in remote villages.

Developing cost-effective cogeneration and district-heating technologies is closely allied with DOE's efforts to improve the overall efficiency and environmental performance of fossil-based power generation, both conventional pulverized-coal and advanced systems.





## ECONOMICAL, RELIABLE, AND CLEAN ON-SITE POWER GENERATION

A compact phosphoric acid fuel cell has been supplying reliable electric power to a hotel in Spokane, Washington, for over a year, demonstrating the high efficiency and ease of installation of fuel cell power generation. This 200-kW ONSI unit was the first commercial fuel cell installation in the northwestern United States. Over 160 units have been manufactured so far, and the technology is speeding through the initial stages of commercialization. Worldwide deployment of the phosphoric acid fuel cell (PAFC) is expected within the next five years, as the need for high-efficiency power technologies with low emission rates increases. Concerns about potential climate change from $CO_2$ emissions will boost sales of fuel cells, as they can reduce $CO_2$ emissions by as much as 60% over those of today's coal plants.

The power generation system of choice in distributed generation scenarios, the PAFC is currently being sold with standard warranties. It is particularly well-suited for use in hospitals, hotels, and computer center, where its quiet, self-contained operation can be installed in modules to match individual customer demand. DOE-sponsored R&D led to the fuel cell's launch on the market, and DOE is now helping to implement its commercialization through the phosphoric acid fuel cell program and supporting research to lower its capital costs.

As in Spokane, where the PAFC supplies a flexible source of supplemental power to baseload electricity, Fuel cells are an ideal component of a diversified portfolio for U.S. power suppliers.